

Fast Manufacture of Silicon Nitride for Aerospace, Defense, and Automotive Industries

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The 27th Annual Cocoa Beach Conference and Exposition
on Advanced Ceramics and Composites
Jan 27, 2003



Outline

- **Introduction**
- **Rapid Prototype**
- **Microwave Processing**
- **Results and Conclusions**

Introduction

Needs

- Rapid Materials Development
- Rapid Materials Qualification
- Compress Time to Manufacture

Solutions

- CAD/CAM
- Rapid Prototype and Fabrication
- Rapid Firing Methods
- Robotic Production

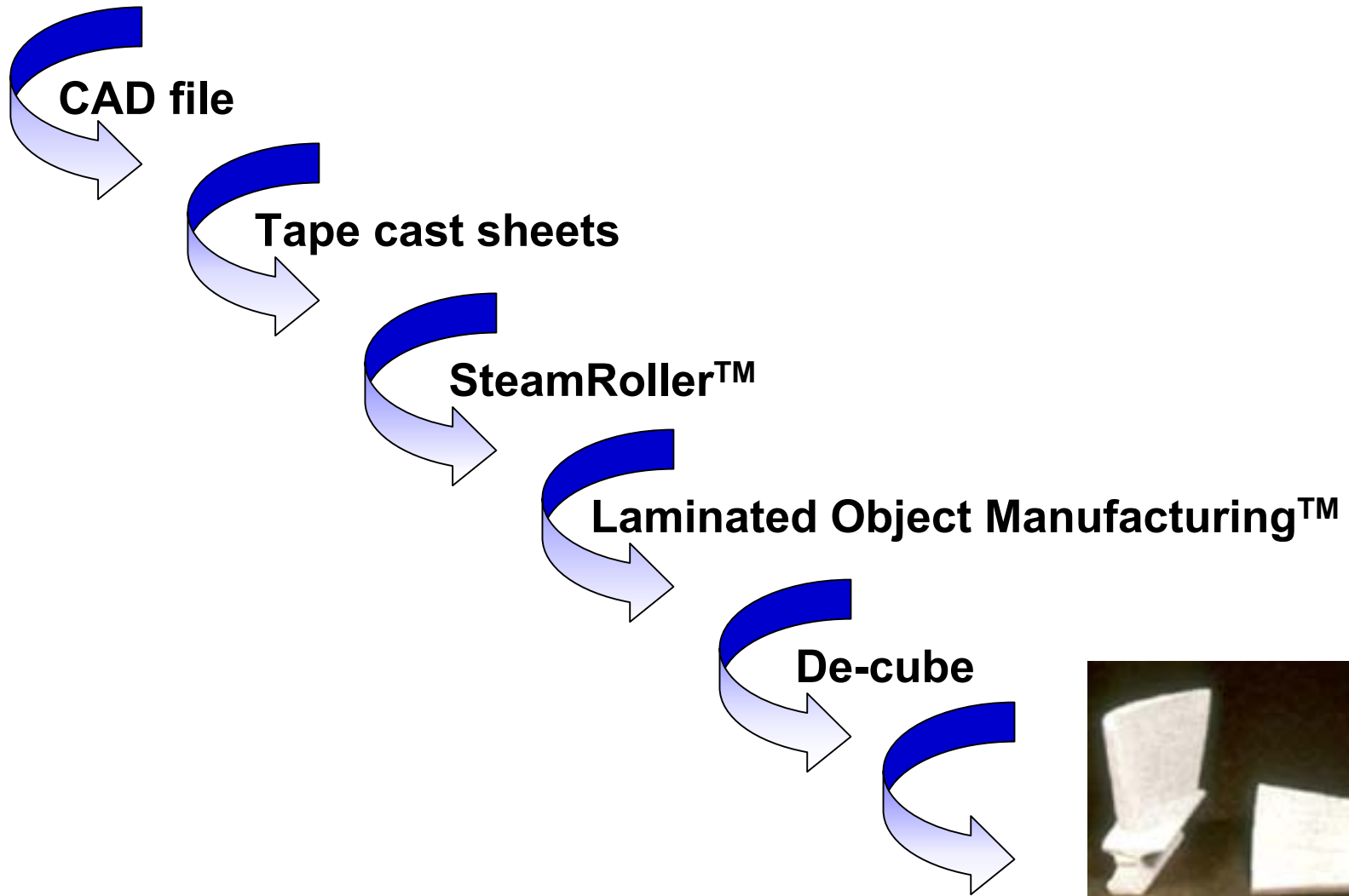
Rapid Prototype/Fabrication

- Laminates
- Printing
- Selective Gelation

Rapid Heating Methods

- Microwave
- Laser
- Plasma
- High Intensity Lamp

Javelin Rapid Prototype Process



Javelin SteamRoller

SR/LOM Solid FreeForm Fabrication System



Factors in Microwave Firing

Susceptors

- Are they necessary?
- Choose susceptor material for the process

Relationship Susceptors and Product Load

- Competing for energy, temp product load takes over?
- Relative mass susceptor vs. load
- Effect of placement of susceptors

Relationship Total Load and Container Volume

- Avoid inverse temperature profile
- Minimize volume to improve heating rate

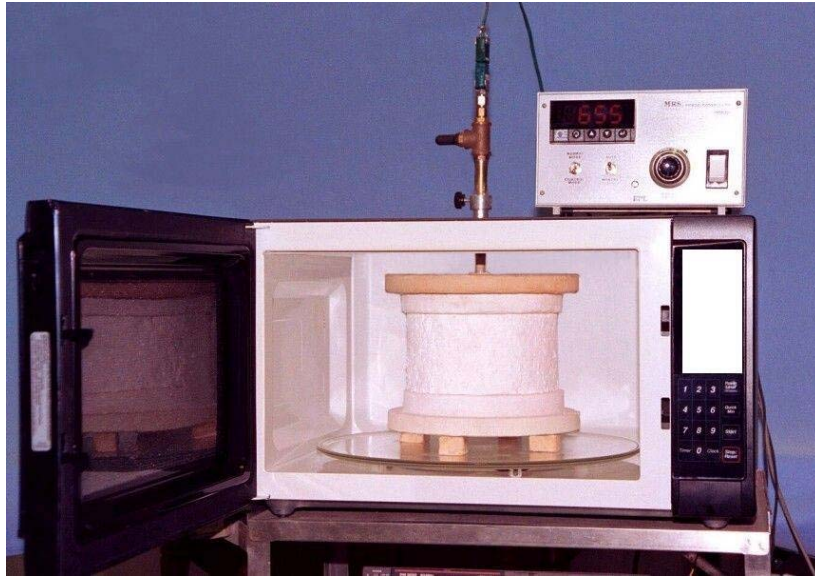
Dielectric Properties

$$\epsilon_r = \epsilon_r' - j \epsilon_r''$$

$$\tan \delta = \epsilon_r'' / \epsilon_r'$$

- Complex permittivity \rightarrow ability to absorb and store energy
- Permittivity (ϵ_r') \rightarrow penetration of microwaves
- Loss factor (ϵ_r'') \rightarrow store energy
- Loss tangent ($\tan \delta$) \rightarrow Convert absorbed energy to **HEAT**

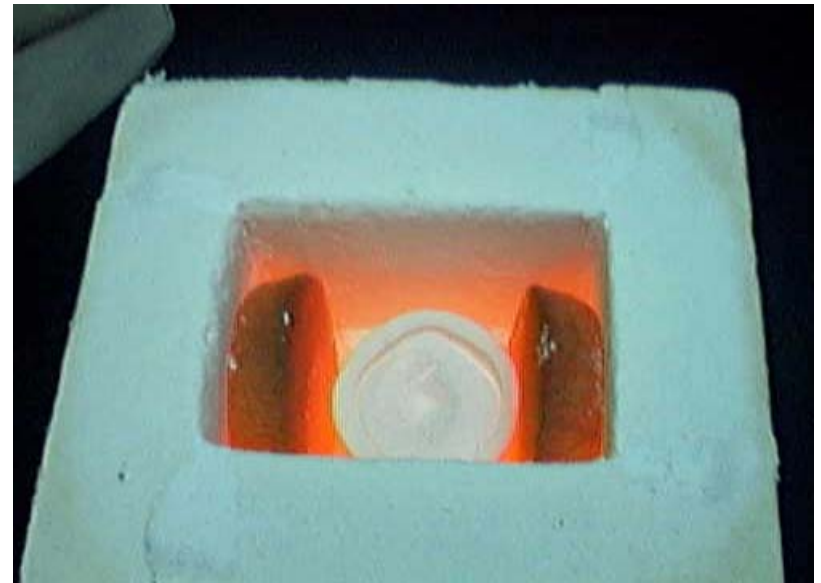
Microwave System



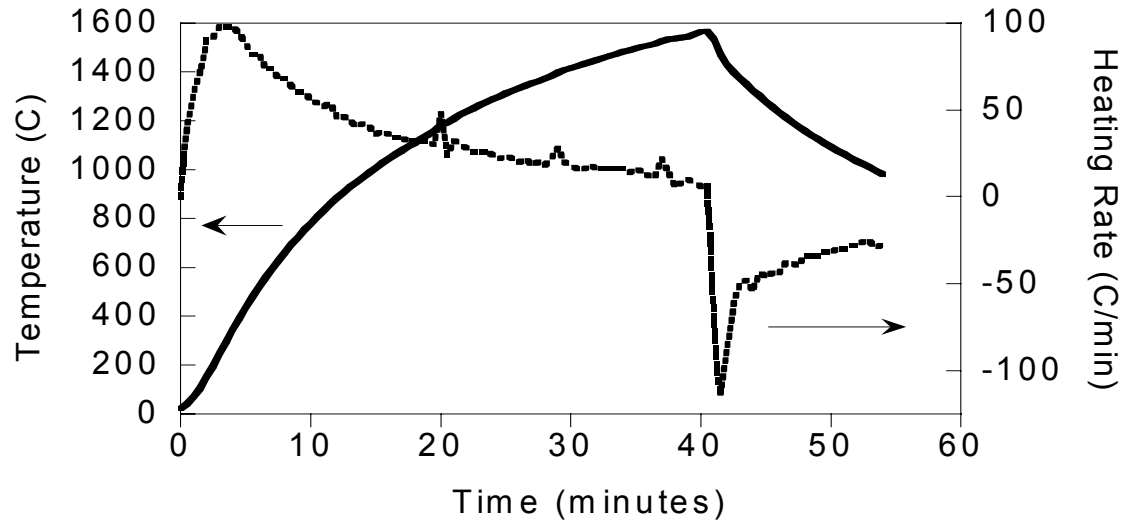
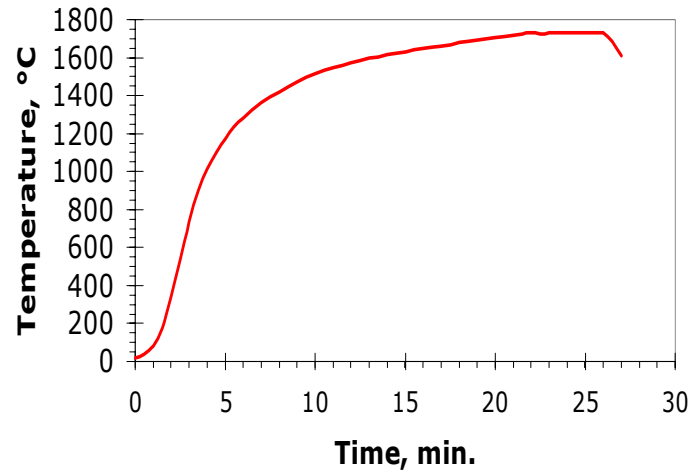
Research Microwave Systems ThermWAVE

1.3 kW, 2.45 Ghz, water cooled

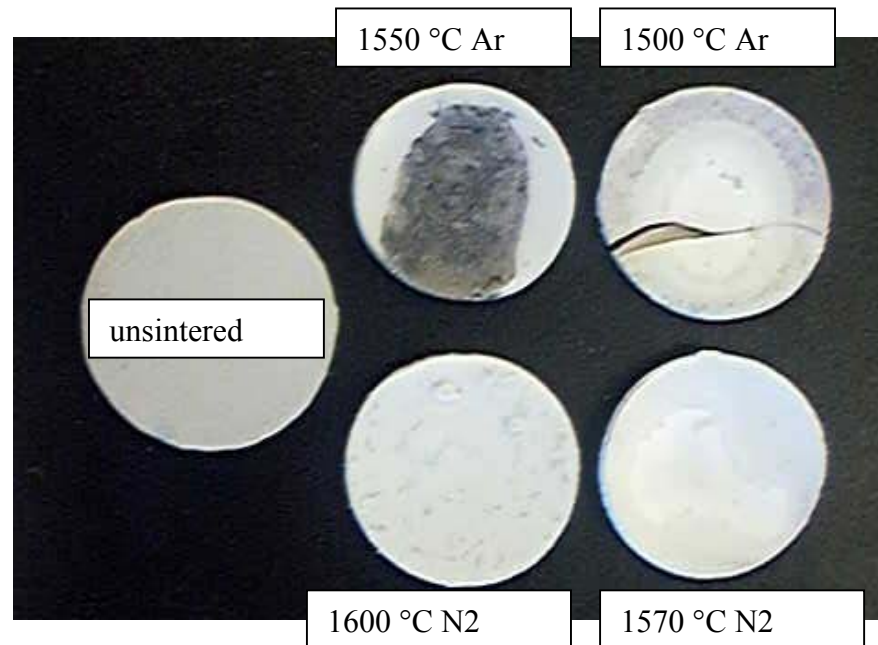
Thermal Package



Microwave Firing Curves



Optimize Microwave Firing Parameters



Results

- Density ~95% theoretical in 1 hour
- Linear shrinkage 15%
- Reproducible
- Microwave Eliminated Warpage and Delamination Defects

Conclusions

- Low Cost Microwave Feasible for Silicon Nitride Sintering
- Lower Reject Rate with Microwave
- Need slightly more power than 1.3 kW or Better Efficiency for Full Density

Acknowledgments

- New York State Energy Research and Development Authority
- Wright Patterson Air Force Base